Institut für Raumfahrtsysteme
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Characterization of CO_2 Plasma Free Stream Conditions for Atmospheric Entry Simulation

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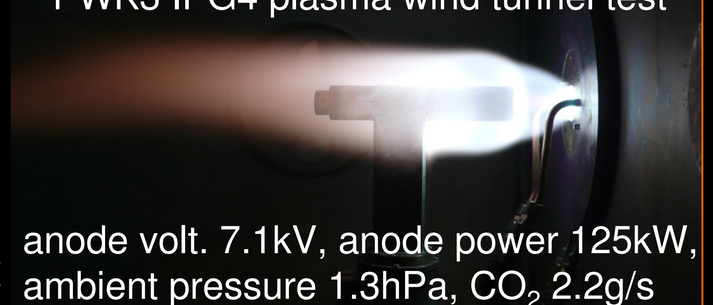
Objectives

- assessment of availability of simulation tools for entry in CO_2 atmospheres
- experimental: characterization of high enthalpy CO_2 plasma jets
- numerical: development of tools to predict convective and radiation heat flux

PWK3 IPG4 plasma wind tunnel test

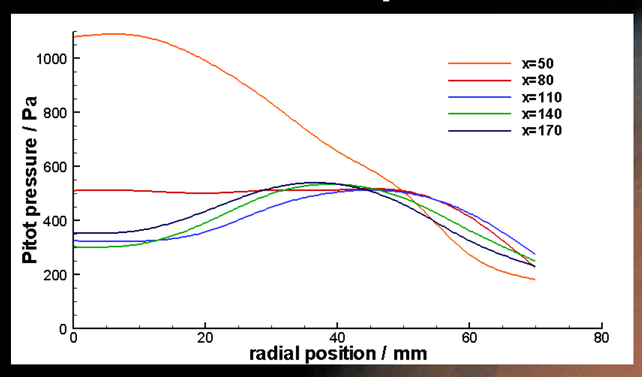


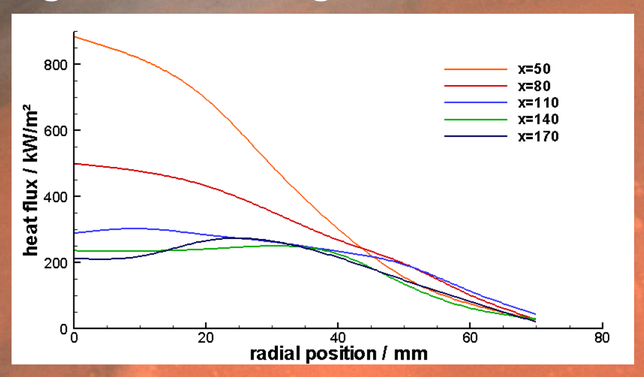
anode volt. 7.1kV, anode power 125kW, ambient pressure 1.3hPa, CO_2 2.2g/s

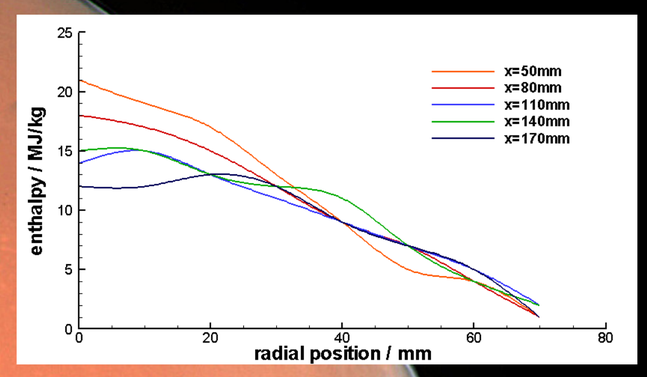
Free Stream Characterization - Enthalpy Determination

- plasma characterization with calorimeter, heat flux and Pitot pressure probes
- enthalpy calculation based on the relationship of Marvin and Pope
- three reference points: 12MJ/kg, 15MJ/kg and 21MJ/kg

$$\frac{h_{tot,e}(x,y)}{h_{Kal,eff}} \approx \frac{R_{Pl}^2}{2} \frac{\frac{\dot{q}}{\sqrt{p_{tot}}}(x,y)}{\int_0^{R_{Pl}} \frac{\dot{q}}{\sqrt{p_{tot}}} y dy}$$

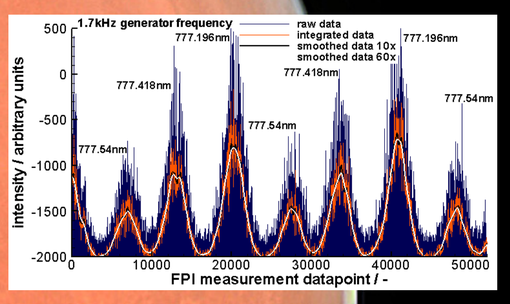


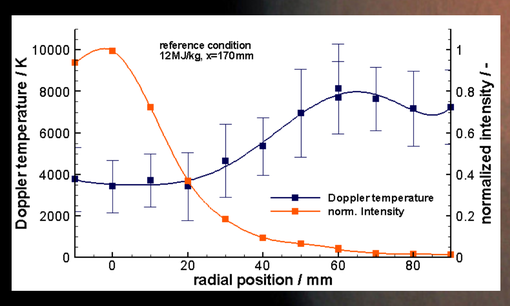


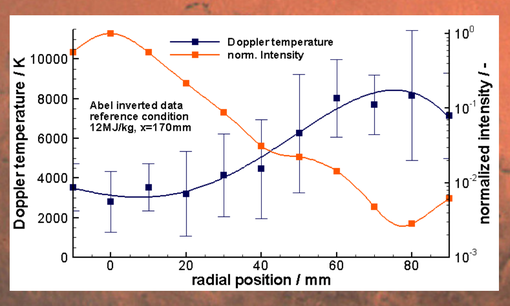


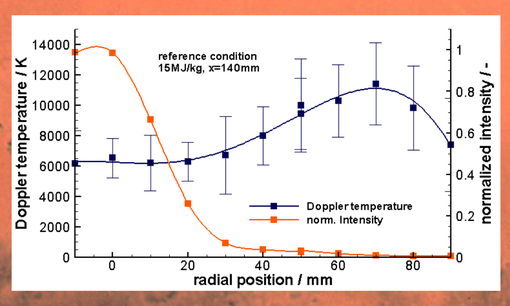
Fabry-Perot-Interferometry

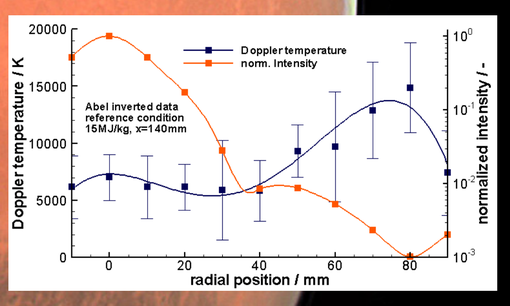
- Fabry-Perot measurements at the 12MJ/kg and 15MJ/kg reference conditions
- 777nm oxygen triplet , resolved in two interference orders, 100pm free spectral range
- Abel inversion to extract spatially resolved information





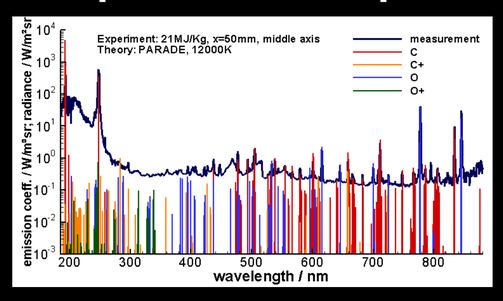


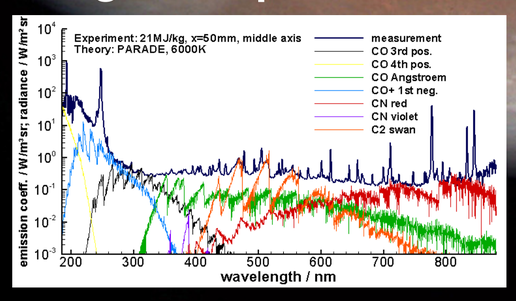


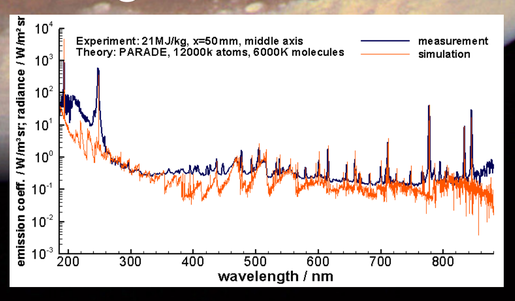


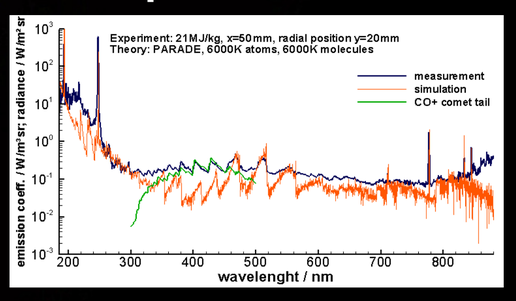
Optical Emission Spectroscopy – PARADE radiation simulation

- optical emission spectroscopic measurements at all reference conditions (12, 15, 21 MJ/kg)
- atomic emission lines of C and O, molecule based emission of C_2 Swan, CO 3rd pos. and CO 1st neg. systems
- comparison with numerical simulations using PARADE, equilibrium calculations of single species
- equilibrium temperatures fitting the experimental data in disagreement with FPI Doppler temperatures









Conclusions

- facilities are available to generate high enthalpy plasma free stream conditions for CO_2 entry simulations
- numerical tools reproduce CO_2 radiation only qualitatively, improvements necessary
  - non-equilibrium models, implementation of all significant molecular bands (i.e. CO^+ Comet-Tail system)

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